

A Database for Propagation Models

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1.0 Introduction

The National Aeronautics and Space Administration's (NASA's) Propagation Program supports academic research that models various propagation phenomena in the space research frequency bands. NASA supports such research via schools and institutions prominent in the field. The products of these efforts are particularly useful for telecommunications systems engineers and researchers in the field of propagation phenomena.

The systems engineer usually needs a few propagation parameter values for a system design. Published literature on the subject, such as the Consultative Committee for International Radio (CCIR) publications, may help, but often the parameter values given in such publications use a particular set of conditions that may not quite include the requirements of the system design. The systems engineer must resort to programming the propagation phenomena models of interest to obtain the parameter values to be used in the system design. Furthermore, the researcher in the propagation field must then program the propagation models either to substantiate the model or to generate a new model. The researcher or the systems engineer must either be a skillful computer programmer or must hire a programmer. This, of course, increases the cost of the effort; an increase in cost due to the inevitable programming effort may seem particularly inappropriate if the data generated by the experiment is to be used to substantiate the already well-established models, or a slight variation thereof.

To help the researcher and the systems engineers, it was recommended by the conference participants of NASA Propagation Experimenters (NAPEX) XV (London, Ontario, Canada, June 28 and 29, 1991) that software should be constructed that contains propagation models and the necessary prediction methods of most propagation phenomena. Moreover, the software should be flexible enough for the user to make slight changes to the models without expending a substantial effort in programming.

2.0 Properties of the Propagation Database

The Propagation Model Database described here creates a user friendly environment that makes using the database easy for experienced users and novices alike. The database allows sufficient freedom for users to custom fit the propagation phenomena model of interest to their requirements. The database is designed to pass data through the desired models easily and generate relevant results quickly. The database contains many propagation phenomena models accepted by the propagation community. Only minimal computer operations knowledge is necessary to run the database.

The models included in the database are published in the NASA Propagation Effects Handbook, CCIR publications, or other publications such as the IEEE Journal, etc. Every model included in the software contains a reference to the document from which the model was obtained, and a brief description of the model itself. Also, when applicable, the related model names are also indicated. The parameters of every model in the database are shown explicitly, and the units of the parameters are defined completely so that the user does not have to invest time investigating them. Wherever possible, to make the use of the model obvious to the user, default values of the parameters are given. The default values are generally values that are used most frequently with the model, the user is free to change them to more appropriate ones. One possible use of the default values is to compare the already known results using the default values with the newly obtained values in an experiment.

User friendly procedures are used to call the available mathematical functions of Excel software, such as curve fitting, statistical analysis, etc. This allows the user to apply these functions to the data whenever needed.

3.0 Software Selection to Host the Propagation Database

A study was conducted to evaluate the advantages and disadvantages of a compiler-based program versus a spreadsheet-based program hosting the propagation database software. The results indicated that spreadsheet or database software (because of its very nature of dealing with data in columns without extra effort) will easily create a final database-type product such as the Propagation Models Database.

Of the many commercially available spreadsheet programs, Microsoft Excel was selected to host the Propagation Models Database. Excel provides an extensive list of the database and mathematical functions necessary to implement the propagation models. Excel also has excellent charting capabilities that include many versions of two- and three-dimensional charts, which can be easily used or automated using the macro language. Excel also offers the dialog box utility, which can be effectively used for input and output functions of the Propagation Models Database.

Another notable advantage of Excel is that it can call any executable programs written in C, which is a compiler-based program. This arrangement is ideal because it combines the advantages of a spreadsheet environment with the speed of the compiler-based software for number-crunching purposes.

The Propagation Models Database Software was created using Excel version 4.0 and uses the dialog box as well as the charting capabilities of this version quite extensively.

4.0 Software and Hardware Requirements

To run the Propagation Models Database, Microsoft Windows 3.1 and Microsoft Excel 4.0, or later versions are required. A personal computer equipped with an 80386 cpu, accompanied by its 80387 math coprocessor chip, with at least 4 Mbytes of RAM, is required to run the software. The clock speed should be at least 20 MHz. An 80486-based system with a higher clock speed is preferable. Any other computer (e.g., an 80286-based PC) with sufficient RAM will run the software, however, it will be very slow.

For the Macintosh version of the database, a Macintosh IIci or better computer accompanied with its coprocessor chip and having at least 4 Mbytes of RAM are needed to run the software. The clock speed should be at least 20 MHz.

It is recommended that a color monitor be used so that the charting can be done more effectively. Also, needed is a hard disk with at least several megabytes of storage space available for the software.

5.0 The Propagation Database

The Propagation Database is divided into six categories: the Ionospheric models, the Tropospheric models, the Land Mobile Systems models, the Effects of Small Particles models, the Rain models, and the Radio Noise models. These six categories are further divided into subcategories to include all the models to be housed in the software.

Ionospheric Models:

Absorption Model and Scintillation Model

Tropospheric Models:

Index of Refraction Profile Model, Gaseous Attenuation Model, Refraction and Fading Model

Land Mobile Satellite System Models:

Cumulative Distribution of Fade Duration Model, Cumulative Distribution of Non-Fade-Duration Model, Cumulative Distribution of Phase Fluctuation Model, Diffusely Scattering Model, Empirical Regression Models, Empirical Roadside Shadowing Model, Large Scale - Small Scale (LS-SS) Coverage Model, Fade State Transition Model, Faraday Rotation Model, Frequency Scattering Model, Geometric Analytic Models, Single Object Model, Multiple Object Scattering Model, Loo's Distribution Model, Log normal Shadowing Model, Raleigh Model, Reflection Coefficient Model, Simplified Log normal Shadowing Model, and Total Shadowing Model

Effect of Small Particles Models:

Cloud Model

Rain Models:

CCIR Model, CCIR Model (Proposed Modification), Global Model, Dutton Dougherty Model, Lin Model, Rice Holmberg Model, and Simple Attenuation Model

Radio Noise Models:

Noise Model

The access to any model is carried out using Excel's dialog box user interface. Each dialog box is divided into six distinct areas to help the user to provide the inputs easily.

The six areas of the dialog box are described below. The first area is used to provide general information about the model selected by the user. This step describes any particular conditions required by the model, the parameter ranges as well as the number of steps the model has, and so on. The second area is used to display formulas describing the model selected. The formula can be modified by the users to a certain extent using legal expressions in Excel. Once the formula is created, the software will use this formula for the current run only. Loading the software again will bring back the original formula. The third area is the input area. This area is used to acquire input parameter(s) for the model. The fourth area is used to display definitions of the input and output parameter(s) used by the model. The fifth area is used to display intermediate or final result(s) of the particular model. The sixth area has a few buttons to help the user and to produce the output(s) of the model (or step). For some models, this area also has buttons to allow creation of a table of output values of the model as a function of the range of the selected input parameter. The following figures show the run of the CCIR rain attenuation model included in the database software.

6.0 Conclusion

A database of various propagation phenomena models that can be used by telecommunications systems engineers to obtain parameter values for systems design is presented. This is an easy-to-use tool and is currently available for either a PC using Excel software under Windows environment or a Macintosh using Excel software for Macintosh. All the steps necessary to use the software are easy and many times self-explanatory; however, following is a sample run of the CCIR rain attenuation model presented.

A Sample Run of the CCIR Rain Attenuation Model

The following pages show a sample run of the CCIR model, which contains 6 steps:

The model used for the effective rain height, h_R , is as follows:

$$h_R = 3.0 + 0.028 * \Phi \quad 0 \leq \Phi < 36^\circ$$

$$h_R = 4.0 - 0.075 * (\Phi - 36) \quad \Phi \geq 36^\circ$$

where

Φ is the station's latitude in degrees.

- Enter Φ (the station's latitude) in degrees, e.g., 30 degrees.
- Click the Output button to see h_R (the effective rain height).
- Click the Step 2 button to go to the next step.

CCIR

This Rain model is used to calculate the long-term statistics of the slant-path rain attenuation at a given location for frequencies up to 30 GHz.
This model has 6 steps, each will appear in a separate dialog box

Step 1 of 6:

*** MODEL ***
Calculate the Effective Rain Height.

If ($0 \leq \Phi < 36$) (deg)
hR (km): $3.0 + 0.028 * \Phi$

If ($\Phi \geq 36$) (deg)
hR (km): $4.0 - 0.075 * (\Phi - 36)$

*** DEFINITION ***
Phi: Station's Latitude
hR: Effective Rain Height

*** INPUT ***
Phi (deg): 37

*** OUTPUT ***
hR (km): 3.99

Reference
Output
Step 2
Close

Step 2: Calculates L_S , the slant-path length below rain height in km.
The model used for the slant-path length, L_S , is as follows:

$$L_s = \frac{(h_r - h_s)}{\sin(\theta)} \quad \theta \geq 5^\circ$$

$$L_s = \frac{2(h_r - h_s)}{\left(\sin^2(\theta) + \frac{2(h_r - h_s)}{R_e} \right)^{1/2} + \sin(\theta)} \quad \theta < 5^\circ$$

where

h_r is the effective rain height in kilometers.

h_s is the height mean sea level of the Earth station in kilometers.

θ is the elevation angle in degrees.

R_e is the modified Earth radius (defaulted to 8500 km).

- h_r was computed in Step 1.
- Enter h_s (the height mean sea level of the Earth station) e.g., 0.632 km.
- Enter θ (the elevation angle) e.g., 14 degrees.
- Change R_e (the Earth radius) if necessary.
- Click the Output button to see L_s (the slant-path length).
- Click Step 3 to go to the next step.

CCIR

This Rain model is used to calculate the long-term statistics of the slant-path rain attenuation at a given location for frequencies up to 30 GHz.
This model has 5 steps, each will appear in a separate dialog box

Step 2 of 5:

*** MODEL ***

Calculate Slant-path Length

If (Theta >= 5) (deg), Ls (km):

$L_s = (h_R - h_S) / \sin(\text{Theta})$

If (Theta < 5) (deg), Ls (km):

$L_s = \frac{(2 * (h_R - h_S))}{((\sin(\text{Theta}))^2 * (2 * (h_R - h_S) / R_e))}$

*** DEFINITION ***

hR: Effective Rain Height
hS: Height above mean sea level of the earth station
Theta: Elevation Angle
Re: Modified Earth Radius (8500 Km)
Ls: Slant-path length below rain height

*** INPUT ***

hR (km): 3.99

hS (km): 0.632

Theta (deg): 14

Re (km): 8500

*** OUTPUT ***

Ls (km): 13.89

Reference

Output

Step 3

Close

Step 3: Calculates L_g , the horizontal projection of the slant-path length in kilometers.

The model used for the horizontal projection of the slant-path length, L_g , is

$$L_g = L_s \cos(\text{Theta})$$

where

L_s is the slant-path length below rain height in kilometers.

Theta is the elevation angle in degrees.

- No input is required for this step.
- Click the Output button to see L_g (the horizontal projection of the slant-path length).
- Click the Step 4 button to go to the next step.

CCIR

This Rain model is used to calculate the long-term statistics of the slant-path rain attenuation at a given location for frequencies up to 30 GHz.
This model has 5 steps, each will appear in a separate dialog box.

Step 3 of 5:

««« MODEL »»»

Calculate Horizontal Projection of the slant-path length.

Lg (Km):

««« INPUT »»»

Ls (km):

Theta (deg):

««« DEFINITION »»»

Ls: Slant-path length below rain height.

Theta: Elevation Angle.

Lg: Horizontal Projection of the slant-path length.

««« OUTPUT »»»

Lg (Km):

Reference

Output

Step 4

Close

Step 4: Obtains $R_{0.01}$ (dB), the rain intensity exceeded for 0.01% of an average year and calculates $r_{0.01}$, the reduction factor.

The model used for the reduction factor, $r_{0.01}$, is

$$r_{0.01} = \frac{1}{1 + L_c/L_o}, \quad L_o = 35 \exp(-0.015 R_{0.01})$$

where,

$R_{0.01}$ is the rain intensity exceeded for 0.01% of an average year in mm/hr.

$r_{0.01}$ is the reduction factor.

- Select the Rain Climatic Zone, such as K for this example.
- Click the Output button to see $r_{0.01}$ (the reduction factor).
- Click the Step 5 button to go to the next step.

CCIR

This Rain model is used to calculate the long-term statistics of the slant-path rain attenuation at a given location for frequencies up to 30 GHz.
This model has 6 steps, each will appear in a separate dialog box

Step 4 of 6:

*** MODEL ***
Obtaining the Rain Intensity, $R_{0.01}$ (mm/hr), exceeded for 0.01% of an average year.
Calculate Reduction Factor, $ro.01$.
 $-1/(1+Lq/L0)$
 Where $L0$ is:
 $-35*EXP(-0.015*R_{0.01})$

*** DEFINITION ***
 $R_{0.01}$: Rain intensity exceeded for 0.01% of an average year.
 $ro.01$: Reduction Factor

*** INPUT ***
Select Rain Climatic Zone:

| | | | | |
|-------------------------|-------------------------|-------------------------|------------------------------------|-------------------------|
| <input type="radio"/> A | <input type="radio"/> D | <input type="radio"/> G | <input checked="" type="radio"/> K | <input type="radio"/> N |
| <input type="radio"/> B | <input type="radio"/> E | <input type="radio"/> H | <input type="radio"/> L | <input type="radio"/> P |
| <input type="radio"/> C | <input type="radio"/> F | <input type="radio"/> J | <input type="radio"/> M | <input type="radio"/> Q |

*** OUTPUT ***
 $R_{0.01}$ (mm/hr):
 $ro.01$:

Reference

Output

Step 5

Close

Step 5: Calculates ΓR , the specific attenuation using the frequency-dependent coefficient in dB/km. The formula used to calculate ΓR is as follows:

$$\Gamma R = k R_{0.01}^a,$$

$$k = [k_H + k_V + (k_H - k_V) \cos^2(\Theta) \cos(2\tau)] / 2$$

$$\alpha = [k_H \alpha_H + k_V \alpha_V + (k_V \alpha_H - k_H \alpha_V) \cos^2(\Theta) \cos(2\tau)] / 2k$$

where

Θ is the elevation angle in degrees.

τ is the polarization tilt angle in degrees.

k and a are coefficients taken from Reports of the CCIR, 1990. Table 1. Regression Coefficients for Estimating Specific Attenuation.

- Enter *Frequency*, e.g., 12.5 GHz.
- Select *Tau*, e.g., 45 degrees for circular polarization.
- Click the Output button to see ΓR .
- Click the Step 6 button to go to the next step.

CCIR

This Rain model is used to calculate the long-term statistics of the slant-path rain attenuation at a given location for frequencies up to 30 GHz.
This model has 5 steps, each will appear in a separate dialog box

Step 5 of 5:

*** MODEL ***

GammaR (dB/km):

*** INPUT ***

Frequency (GHz):

Theta (deg):

Tau (deg):

☐ 0 deg: vertical polarization

☒ 45 deg: circular polarization

☐ 90 deg: horizontal polarization

*** DEFINITION ***

GammaR: Specific Attenuation using the frequency-dependent coefficient.

Theta: Elevation angle.

Tau: Polarization tilt angle.

k and Alpha are coefficients taken from Table 1 - Regression coefficients for estimating specific attenuations of flaps of the CCIR, 1990.

Reference

Output

Step 5

Close

*** OUTPUT ***

GammaR (dB/km):

Step 6: Calculates $A_{0.01}$, the attenuation exceeded for 0.01% of an average year in decibels.

The formula used for the attenuation exceeded for an average year, $A_{0.01}$ is:

$$A_{0.01} = \text{GammaR} * L_s * r_{0.01}$$

where

GammaR is the specific attenuation using the frequency dependent coefficient in dB/km.

L_s is the slant-path length below rain height in kilometers.

$r_{0.01}$ is the reduction factor.

Click the Output button to see $A_{0.01}$ (the attenuation exceeded for 0.01% of an average year).

Click the "Other p (%)" button to find attenuation exceeded for other percentages of an average year (0.001 to 1.0 %).

CCIR

This Rain model is used to calculate the long-term statistics of the slant-path rain attenuation at a given location for frequencies up to 30 GHz.
This model has 5 steps, each will appear in a separate dialog box

Step 5 of 5:

*** MODEL ***
Calculate Attenuation Exceeded for an average year

A0.01 (dB):

*** INPUT ***

*** DEFINITION ***
A0.01: Attenuation Exceeded for 0.01% of an average year.

*** OUTPUT ***

A0.01 (dB):

Click the 'Other p' button to find attenuation to be exceeded for other percentages of an average year, ranging from 0.001 to 1.0 %.

Reference

Output

Other p (%)

Close

This step also calculates attenuation exceeded of an average year for other percentages (0.001 - 1.0 %).

The formula used for p percent of the attenuation exceeded of an average year is as follows:

$$A_p = A_{0.01} * 0.12 * p^{-(0.546 + 0.043 \log(p))}$$

where

- p is the percentage of the attenuation exceeded.
- A_p is the attenuation exceeded for p percent.
- $A_{0.01}$ is the attenuation exceeded for 0.01 percent.

- Enter the p (percentage) of an average year.
- Click the Output button to see A_p , attenuation of p percentage and ratio of $A_p/A_{0.01}$

CCIR

This Rain model is used to calculate the long-term statistics of the slant-path rain attenuation at a given location for frequencies up to 30 GHz.

| | |
|--|--|
| <p>*** MODEL ***</p> <p>A(p)</p> <p>A(0.01)</p> <p>$-A(0.01) * (0.12 * (p^{-(0.546 + 0.043 * \text{LOG}(p))}))$</p> | <p>*** INPUT ***</p> <p>p (%)</p> <p>0.1</p> |
| <p>*** DEFINITION ***</p> <p>p: Percentage of Attenuation Exceeded of an average yr.</p> <p>A(p): Attenuation Exceeded for p % of an average yr.</p> <p>A(0.01): Attenuation Exceeded for 0.01 % of an average yr.</p> | <p>*** OUTPUT ***</p> <p>A(p) (dB):</p> <p>5.60</p> <p>A(p)</p> <p>0.38</p> <p>A(0.01)</p> |

When the close button is clicked the following dialog box appears

Microsoft Excel

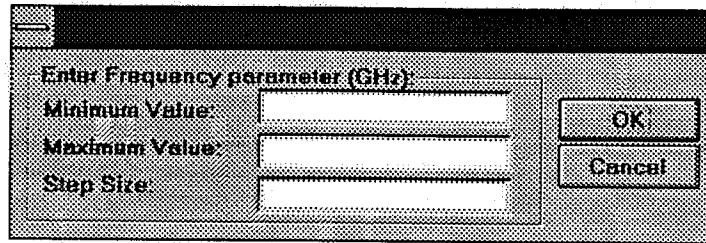
Do you want to chart or create table?

- Click OK to see the response.

Chart

☐ Rain Rate vs. Attenuation
 ☒ Frequency vs. Attenuation

- Select one of the options, e.g., the Frequency vs. Attenuation.
- Click OK.



- Enter the minimum, maximum and step values
- Click OK

A new worksheet will then be invoked to store all of the parameters used, and the table, as well as the selected chart.

The 'Print' option is available after this step.

This ends the sample run of the CCIR model.

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NAPEX XVIII

Session 2

**PROPAGATION STUDIES FOR
MOBILE, PERSONAL, AND SOUND
BROADCAST SYSTEMS**

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